A STUDY OF THE EFFECT OF STARVATION UPON BEHAVIOR BY MEANS OF THE OBSTRUCTION METHOD

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FRANCES HOLDEN

Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy, in the Faculty of Philosophy, Columbia University

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This investigation was made in the Animal Laboratory of the Department of Psychology, Columbia University, under the direction of Dr. C. J. Warden to whom the writer wishes to express her gratitude for constant suggestions and criticism. The writer also is greatly indebted to Dr. T. N. Jenkins for his development of the electric control mechanism here used. Thanks are also due to Prof. R. S. Woodworth and Dr. H. E. Garrett for their advice in the preparation of the manuscript, and to Mr. Thomas W. Tichenor and Mr. Raymond P. Holden for assistance in the taking of the data.

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I. INTRODUCTION

The present study is an attempt to measure the drive,[1] or motivation value, of starvation in the white rat in terms of ob-

[1] The term hunger drive as used in this study, means nothing more than that the animal displayed a food searching response. The term carries no implications whatsoever concerning the presence or absence of so called "hunger contractions" of the stomach, or concerning the subjective state of the organism.

jective behavior. For this purpose the Obstruction Method has been employed.[2] This method involves the principle of placing an obstruction of some sort between the animal to be tested and an incentive stimulus, selected with reference to the drive under investigation. The animal is required to pass over the obstruction (in the present case an electric grill) in order to reach the incentive stimulus and thus satisfy the drive dominant at the moment. A quantitative determination of the strength of the drive can thus be secured in terms of the behavior of the animal toward the obstruction-incentive situation. By keeping the obstruction constant and varying systematically the physiological state of the organism from which the drive results (as would occur for example in the case of the hunger drive with a series of starvation periods of different length) it is possible to obtain indices of the motivation value of different organic states in relation to a specific stimulus. By keeping the obstruction constant it is also possible to obtain comparable data concerning the relative strength of different drives. This method is in general principle an elaboration of that used by Moss (7) in his study of animal drives. However, as will appear from the later discussion, the apparatus and procedure here used differ radically from that used by him.

The present investigation includes two main problems. The first is the determination of the effect of systematic variation of the period of starvation upon drive behavior when a constant amount of electrical stimulation is employed in the obstruction section. The second deals with the relative effect of three different degrees of electrical stimulation in the obstruction compartment upon the drive behavior resulting from a series of starvation periods.

The only previous work bearing direct relation to this study is that of Moss (7). The chief aim of Moss's study as he states, was to suggest various methods by which the problem of animal drives might be studied. In this respect his work is extremely

[2] For a full discussion of the development and uses of the Obstruction Method see Jenkins, Warner and Warden, Standard Apparatus for the Study of Animal Motivation.

valuable. He did not, however, develop to any considerable degree of refinement any of the various methods used by him; nor does he claim any great validity for the results he obtained. The chief method suggested by Moss is similar in general principle to that more fully developed in the present study and termed the Obstruction Method. By this method Moss considered the effects of starvation periods ranging from 12 to 144 hours on the behavior of the albino rat. He found that with a 12-hour hunger period none of the rats crossed a 20-volt resistance placed between them and the food stimulus, though given an hour in which to do so. With the 24-hour group 1 rat crossed to the food stimulus. With the 48-hour group 3 crossed and with the 72-hour group all 4 crossed. The 8 rats that had failed to cross in these groups were given a retrial with 96 hours starvation, and of these 4 crossed. Of the 4 rats that had still failed to cross 2 did so after 120 hours and the remaining 2 after 144 hours starvation. Moss concludes that the tendency to cross the grill increases with the length of the starvation period. This conclusion cannot be regarded as offering a final solution of the problem, however, since only 4 rats were used in the 12-, 24-, 48- and 72-hour groups and the results of the 96-, 120- and 144-hour groups involved the reuse of animals that had failed to cross in the earlier groups. Moss does not state the age of the animals he used, which is an obviously important factor in a study of this type. His results consequently cannot be directly compared with those of the present study.

Moss also made a comparison of the sex and hunger drives by the method of choice. This method has been further developed by Tsai (15) and used by him in comparing a 24-hour hunger period with the sex drive.

Moss further considered the relative effect of different drives on maze learning. This method had, however, been previously employed by Szymanski (13, 14) and Simmons (10). Szymanski used the maze both for the determination of the relative effects of different drives on learning and for the study of the effect of different hunger periods on learning. He found in the latter case that with a 30-minute, 4-hour, and 24-hour hunger period,

the most rapid learning occurred with the 24-hour period, while the 30-minute period was least effective.

Simmons used both a simple and complex maze for a comparison of the effect of different food incentives and of different drives on learning. Since a constant hunger period was used throughout her study the results have little bearing on the present work.

Dodson (3) studied the effect of different periods of starvation on the development of a dark-light discrimination habit in the white rat. He used starvation periods of 24, 31, 41 and 48 hours and found that for rats 78 days old, the optimum starvation period for habit formation of this type was 41 hours; however for retention of the maze habit after 21 days, the 48-hour period appeared to be more effective.

Studies of the effect of different periods of starvation on general bodily activity as measured by an "activity cage" have been made by Richter and Nicholls. Richter (9) found that white rats lived 8 days when water but no food was provided, reaching a maximum degree of activity between 2 and 3 days. After three days the activity decreased gradually until death which occurred on the eighth day. When neither water nor food was provided the rats showed an immediate decrease in activity which was continuous until death which occurred on the fifth day. A similar study was made by Nicholls (8) upon the guinea pig. She found that the maximum degree of activity occurred on the second day of starvation and was followed by a marked decline on the third day.

Of the above investigators it appears that Szymanski, Dodson, Richter, Nicholls and Moss have each considered the effect of a series of starvation periods of different length upon behavior. Moss alone, however, used a method in any way comparable with the present one. The other investigators either measured general activity by means of some form of "activity cage" or investigated the relation of starvation to speed of habit formation. Essential differences in method make a comparison of these results impossible. From the small amount of work so far reported it is evident that the relative motivation value of different starvation periods has not been adequately determined. The present

investigation is offered as a contribution toward the solution of this problem.

II. APPARATUS AND PROCEDURE

The apparatus used in this study consisted of a control box for testing the animal and a mechanism for the control of the current supplied to the grill. The general plan of this apparatus

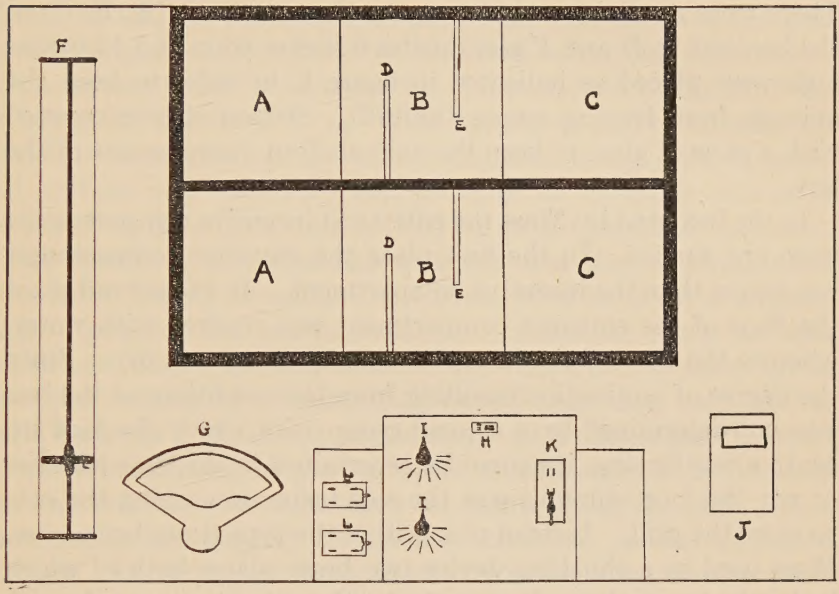

FIG. 1. DIAGRAM OF CONTROL BOX AND ACCESSORY MECHANISMS (WIRING OMITTED)

A, entrance compartment; *B*, obstruction compartment; *C*, incentive compartment; *D* and *E*, glass plates; *F*, potentiometer; *G*, voltmeter; *H*, switch controlling voltmeter; *I*, multipoint switches controlling each resistance unit; *J*, microammeter; *K*, intake switch; *L*, *L* switches throwing current into grills.

is shown in figure 1. A second control box was also provided in order that two animals might be tested simultaneously. Each control box was divided into 3 sections, each of which was 10 inches wide, 10 inches long and 10 inches high. The entire box was painted a dull black. Sections *A* and *C* were made identical in every respect in order that any possible preference for either section might be obviated.

Section *A* was used throughout as the entrance compartment, section *C* as the incentive compartment. The floor of section *B* was made of a slab of bakelite 0.5 inches thick, wound with no. 18 copper wire at intervals of 0.25 inches in such a way that the wires from each terminal alternated, thus insuring a shock when any two adjacent wires were touched. The terminals of these wires were connected with the electric control apparatus. There were no divisions between the three sections (*A*, *B*, *C*) of the box but at *D* and *E* glass plates 6 inches wide and 12 inches high were placed as indicated in figure 1, in order to keep the animals from leaping across the grill. Section *A* was covered with a pane of glass to keep the animals from jumping out of the box.

In the box used by Moss the entry and incentive compartments were not similar. In the first place the entrance compartment was larger than the incentive compartment. In the second place the floor of the entrance compartment was covered with water, whereas the floor of the incentive compartment was dry. Since the degree of motivation resulting from the conditions of the box was not determined by a control group with which the food incentive was lacking, it cannot be ascertained in this case whether or not the food stimulus was the sole factor in causing the rats to cross the grill. Instead of a grill of the type described above, Moss used as a shocking device two brass plates both of which had to be touched simultaneously for the animals to experience a shock. A grill presenting a continuous stimulation surface, such as was used in the present study has certain obvious advantages over this simpler device.

The current supplied to the grill was controlled by means of a General Electric potential transformer and voltage changes were secured by means of the potentiometer, *F* (fig. 1). The electric pressure was measured at the beginning of each experiment by means of a high tension voltmeter, *G*, in order to obviate any deviations in the current supplied, adjustment being made by means of the potentiometer. The voltmeter when not in use was thrown out of the circuit by means of a snap switch, *H*. The current was regulated by means of variable resistance units each

of which was controlled by means of a multipoint switch, *I*. Each resistance unit contained eight elements each having a resistance of approximately 1,250,000 ohms. The multipoint switches made possible a cumulative variation of the resistance in equal steps from 100,000 to 10,000,000 ohms. The current supplying the grills was measured by a microammeter, *J*. The method of wiring made possible, by means of the double throw knife switch, *K*, the measurement of the current in either grill (one for each control box) by one fixed measuring instrument. The current could be thrown into either or both of the grills by closing the switches, *L*, *L*. This apparatus makes possible an exact determination of the current supplied to the grills in terms of voltage and resistance and provides an adequate means of controlling the current and of varying it in systematic amounts. This control is a decided improvement over that of Moss, since the latter merely considers the current used in terms of voltage and disregards the resistance factor. Moreover, since the skin resistance of the animals undoubtedly varies greatly from rat to rat the amount of stimulation received must also vary, unless this factor is in some way eliminated. Moss attempted to overcome this difficulty by placing water in section *A* so that the feet of the animals were moistened on approaching the grill. This method is not entirely satisfactory however, as was indicated above. In the present study this factor was eliminated to as great an extent as possible by using a very large resistance within the electric circuit and thus rendering negligible the resistance of the rats. Since the resistance here used ranged from 3,850,000 to 10,100,000 ohms, it is believed that any variability in resistance in the rats is rendered practically negligible, thus insuring a constant degree of stimulation.

The following current values were used in this study:

	MILLIAMPERES	RESISTANCE (OHMS)	VOLTAGE
Shock 1	0.12	10,100,000	1,200
Shock 2	0.19	6,350,000	1,200
Shock 3	0.32	3,850,000	1,200

A total of 803 albino rats were used in this investigation.[3] The size of each of the 21 groups studied is indicated in table 1 which also shows the arrangement of starvation periods. With the 60- and 72-hour starvation periods many animals died due to the length of the starvation period, thus introducing a selective factor into these groups, which makes them not entirely comparable with the earlier groups. This factor is, however, not great except in the case of the 72-hour groups.

The rats used with shock 1 were highly uniform weighing between 80 and 100 grams and were approximately 8 weeks old. Those used with shock 3 were slightly more variable in size weighing between 80 and 110 grams but were of approximately the same age as those of shock 1. Those used with shock 2 were in general similar to those of shock 1 with the exception of half of the 12-, 24-, 48-, 60- and 72-hour groups which were similar to those of shock 3.

TABLE 1

Showing number of rats used in each starvation group

A indicates number of rats given preliminary training; B, number used in experiment proper; C, number that died during starvation period.

GROUP	SHOCK 1			SHOCK 2			SHOCK 3		
	A	B	C	A	B	C	A	B	C
Control	20	20	20	20	20	0	20	20	0
12-hour	37	37	0	40	40	0	40	40	0
24-hour	40	40	0	39	39	0	40	40	0
36-hour	40	40	0	40	40	0	40	40	0
48-hour	40	40	0	40	40	0	40	40	0
60-hour	41	35	6	40	40	0	53	40	13
72-hour	40	21	19	44	21	23	49	37	12

The rats were kept in the laboratory for one week before being given the preliminary training, in order that they might become adjusted to the laboratory conditions. During this period they were fed milk-soaked bread in their cages at noon each day.

[3] In view of the large number of rats used in this experiment an autopsy of the animals to determine the presence or absence of food in the stomach could not be made.

The preliminary training consisted of placing the animals in groups of ten in section *A* and allowing them to run to the food in section *C* or explore freely within the box for 10 minutes. During this preliminary training there was of course no current in the grill. This procedure was repeated for three consecutive days, in order that the animals might become accustomed to the conditions of the control box.

In order to determine whether the food incentive was the sole factor causing the rats to cross the grill, a control group was used with each degree of shock. The preliminary training of these groups was the same as for the other groups except for the fact that section C contained no food while they were in the box. The control groups were fed immediately after being removed from the box.

In the experiment proper each rat was placed individually in section *A* with the current turned on in the grill and a dish of milk-soaked bread in section *C*. The behavior of each rat was recorded during the test period of 10 minutes. If any animal crossed the grill during the test period it was allowed a nibble of food and immediately returned to *A*. If a rat crossed the grill continuously (i.e., with only momentary pauses upon being returned to section *A*) a nibble was allowed after every third cross.

The procedure for the control group was the same as that for the starvation groups except for the fact that there was no food stimulus in section *C*. The experiment proper, occurred in the case of the control group, 12 hours after the last period of preliminary training. The control group is consequently equivalent to the 12 hour group in every condition but the absence of the food incentive.

The following types of behavior were recorded for each animal during the 10-minute test period: (*a*) crossings, (*b*) contacts, (*c*) jumps. The term crossing indicates that the animal actually crossed the grill and entered the incentive compartment. This measure appears to be the most significant of the three types, inasmuch as it represents the only reactions which resulted in satisfaction of the hunger drive.

By the term contact is meant that the animal merely touched

the grill and withdrew upon being shocked, remaining in the entrance compartment. Partial crossings of the grill, followed by return to the entry compartment (instead of proceeding into the incentive compartment) were scored as contacts. Data concerning contacts are obviously important not only as indicating an attempt of the animal to react positively to the incentive stimulus but also as a measure of the conditioning process resulting in many cases in a negative reaction to the grill. Contacts are in reality frustrated crossings and thus are closely related to the latter type of behavior. It has, however, seemed advisable to consider the two kinds of activity separately.

The term jump refers to the behavior of the animal in the entrance compartment. A jump was checked only when the animal cleared the floor with all four feet. This type of activity seems to indicate an attempt to escape from the entrance compartment. This reaction was probably in most cases the result of the shock, since jumping did not occur until after the first experience with the grill.

The test period of every group in the experiment proper was so arranged as to fall between 3 and 6 p.m. The last of the three periods of preliminary training preceded the experiment proper by the number of hours of starvation requisite for each group. Consequently the preliminary training of the control, 12-, 36- and 60-hour groups was given at 4:30 a.m. while that of the 24-, 48- and 72-hour groups was given at 4:30 p.m.

III. PRESENTATION OF RESULTS

The quantitative results of this study, covering both the effect of different periods of starvation and different degrees of shock on drive behavior are presented in tabular and graphic form as follows:

Tables 2, 3 and 4 are distribution tables for shocks 1, 2 and 3 respectively, covering in each case the three types of behavior—crossings, contacts, and jumps—for each starvation group.

Tables 5, 6 and 7 give the main results of shocks 1, 2 and 3 respectively, for each starvation period. Columns 2 to 5 of these

TABLE 2

Distribution table covering crossings, contacts and jumps under shock 1

DISTRIBUTION	CROSSINGS							CONTACTS							JUMPS						
	C	12	24	36	48	60	72	C	12	24	36	48	60	72	C	12	24	36	48	60	72
0	6	8	4	1				2	0	6	7	7	2	1	15	8	7	8	20	9	8
1	6	5	1	1		3		8	7	15	6	8	9	7		8	4	6	6	4	6
2	6	3		2		5	1	7	7	7	3	9	6	6	2	6	7	3	3	2	1
3	1	2	2			4	1	2	3	2	6	4	10	6	1	3		4	1	4	1
4		1	3			3	2	1	5	3	6	3	2	1		2	2	4	2	1	1
5		3			2	1	1		2	4	7	4	3			5	6	1	3		1
6			1		1	2	4		3	1	1	3			1	3	3	3		4	
7					3	3			4		1	1	1				3	4	3	4	1
8				1	1	2			2		2		2				1	1	1	1	
9			1		2		1		1	1	1				1	1				2	
10		1				1				1								1			1
11				1		1			2			1					4			1	1
12	1			1					1									3			
13		1			2	2											1				
14																				1	
15						1	1											1			
16							1														
17					2													1			
18		1		1													1			2	
19																					
20		1	1	2		1															
21			1		1	1															
22			1		1														1		
23		1	1	1	2		1														
24				2	3		2														
25		1		1		1															
26																					
27			2				1														
28			3	1																	
29			1				1														
30					1		1														
31			1		1																
32				1												1					
33																					
34		1		1	1	1	1														
35					1																
36		1	1	2	1																
37			3				1														
38				1	1																
39					1																
40		1	4	1	2													1			
45		1	3	3	4	1															

TABLE 2—*Continued*

DISTRIBUTION	CROSSINGS							CONTACTS							JUMPS						
	C	12	24	36	48	60	72	C	12	24	36	48	60	72	C	12	24	36	48	60	72
50			3	3	3	1															
55		2		2	1	1															
60		1	1	2																	
65				3	1		1														
70		1		1	1																
75		1	1	1																	
80				3	1																
85				1																	
90																					
95			1																		

The notation C refers to the control group, the numbers 12, 24, 36, 48, 60 and 72 to the series of starvation periods.

The interval of the distribution from 0 to 40 is 1, from 40 to the end of the scale, 5.

This table should read as follows: Control group: 6 rats crossed 0 times, 6 rats crossed once, 6 rats crossed 2 times, 1 rat crossed 3 times, etc.

tables give the measures of central tendency for crossings (median, average, S.D. and C.V.). Columns 6 to 10 give measures of the extreme tendencies for crossings. Column 6 indicates the range of crossings with each starvation group. Column 7 shows the per cent of rats that were immediately conditioned in each group (*i.e.*, of those rats that did not cross the grill after their preliminary experience with it. The first experience with the grill may be either a crossing or a contact). This figure indicates the percentage of rats with which the resistance offered by the grill was at the outset stronger than the hunger drive. Column 8 gives the percentage of animals that crossed the grill only 5 times or less. The number 5 was chosen because the distributions of the groups indicated that the majority of rats with which the resistance soon proved stronger than the hunger drive, were conditioned by 5 crossings or less. Column 9 gives the percentage in each group that crossed 40 or more times. This number was arbitrarily chosen because few of the animals crossed more than 40 times within the test period. Column 10 shows the percentage of rats that failed to be conditioned against the grill

TABLE 3

Distribution table covering crossings, contacts and jumps under shock 2

INTERVAL	CROSSINGS							CONTACTS							JUMPS						
	C	12	24	36	48	60	72	C	12	24	36	48	60	72	C	12	24	36	48	60	72
0		10	7	8	2	2	3	7	8	1	1	1	5	1	8	23	12	19	15	18	12
1	7	2	9	3	5	5	1	5	5	8	3	11	11	3	3	5	5	10	5	11	
2	8	7	6	6	1	8	2	5	8	12	12	5	7	4	3	3	5	4	6	1	1
3	2	4	3	8	1	6		2	5	9	12	7	7	4	1	4	1	3	2	4	2
4		2	1	3	5	3		1	7	3	4	6	6	1	2	1	3	1	2	1	1
5		1		2	1	3	3		2	1	6	2	2	1		2	4		1	1	1
6			1				1		4	1		4	1	3			4	1	2	2	1
7		1	1				1			2	1		1	3	1		3	1	1	1	1
8		2	1	1		1	1			1		1				1			1		
9					1							1			1				1		
10	1	1					1		1		1			1					1		1
11			1	1	1	1	1					1			1						
12						1										1					
13		2				2				1							1				
14		2																	2		1
15				1			2														
16							1													1	
17					2																
18		1																			
19					1												1				
20		1		1	1	1						1									
21				1	1	1	1														
22		1					1														
23																					
24																					
25						2															
26					1																
27			1		2		1														
28		1																1			
29	1				1																
30																					
31					1	1															
32																					
33			2		1																
34																					
35																					
36	1				1														1		
37																					
38																					
39				1	1																
40			1	2	3	2															

TABLE 3—*Continued*

INTERVAL	CROSSINGS							CONTACTS							JUMPS						
	C	12	24	36	48	60	72	C	12	24	36	48	60	72	C	12	24	36	48	60	72
45		1	2		3	1															
50			1		2		1														
55				1	1																
60			1	1																	
65																					
70			1																		
75					1																
80																					
85																					
90																					
100																					
105		1																			

See legend accompanying table 2.

(*i.e.*, were still crossing the grill at the end of the 10-minute test period). This measure indicated the number of animals within each group with which the hunger drive was still stronger than the resistance offered by the grill after a 10 minute experience with it. Columns 11 to 14 give the measures of central tendency for contacts (median, average, S.D. and C.V.). Columns 15 to 18 give the same measures of central tendency for jumps.

Tables 8, 9 and 10 for shocks 1, 2 and 3 respectively, give the reliability of the difference between each two starvation groups with the same degree of shock. (Reliability is stated in terms of the ratio of the difference between two groups to the S.D. of that difference.)

Table 11 indicates the relative effect of the 3 degrees of shock upon the various starvation groups.

Table 12 shows the reliability of the difference between any two shocks with a given starvation group.

Figures 2, 4 and 5 show the cumulative percentile distributions for crossings for shocks 1, 2 and 3 respectively. These figures make possible a point to point comparison of any decile in the distribution of one group with any decile of any other group with which the same degree of shock was used.

TABLE 4

Distribution table covering crossings, contacts and jumps under shock 3

INTERVAL	CROSSINGS							CONTACTS							JUMPS						
	C	12	24	36	48	60	72	C	12	24	36	48	60	72	C	12	24	36	48	60	72
0	2	3	4	2	6	4	2	5	6	6	1	6	4	3	7	9	14	11	12	9	13
1	7	4	4	7	7	4	3	7	10	9	4	11	6	7	2	7	8	4	6	6	5
2	4	12	3	4	6	9	3	4	15	6	10	5	8	4	2	5	4	2	4	5	3
3	1	5	4	4		1	6	2	3	6	10	7	10	8		3	4	5	1	1	3
4	1	5	2	2	4			2	1	4	4	6	2	8	1	2	1	2	4	4	3
5	1	1	1	2	4	1	1		3	8	5	2	4	2		5		3	2	1	
6	1		1	4		3	1		1	1	2	2	3	3	1		2	4	2	4	2
7		1	1	1	1	1	3		1			1	1	1	2	1	2	2	2	2	1
8	1		2		1	1					2		1			1	3	2		2	
9											1				2			2	2		2
10						1									1	2		1	1		1
11		1				2	2							1		1	2				
12					1	2					1					2		2	1	4	
13			1				2									1					
14		1	1	1			2									1			1		
15				1	1		1								1				1	1	3
16				1		1															
17		1	1			2															
18	1																				
19		1				1	1														
20			1	1	1		1														1
21																					
22					1	2															
23			1			1							1								
24			1																	1	
25			1																		
26		1				1															
27		1																			
28			1	1																	
29					1		1														
30					1																
31		1			1																
32				1			3								1				1		
33				1																	
34				1																	
35				1																	
36			1																		
37		1			1	2	1														
38																					
39				1			1														
40		1	1	1																	

TABLE 4—*Continued*

INTERVAL	CROSSINGS							CONTACTS							JUMPS						
	C	12	24	36	48	60	72	C	12	24	36	48	60	72	C	12	24	36	48	60	72
45			2	1	1		2														
50	1		3	1																	
55					1																
60																					
65						1															
70					1		1														
75			2	1																	
80																					
85																					
90			1																		
95																					

See legend accompanying table 2.

Figure 3 shows graphically the effect of the different starvation periods upon the central and extreme tendencies of each group with shock 1.

Figure 6 shows graphically the median number of crossings made by each starvation group with each degree of shock.

The results of this study will be considered in two sections. The first section is concerned with the effect of the series of different starvation periods upon behavior in the obstruction-incentive situation. The second section will consider the effect of different degrees of shock upon behavior when the preceding starvation period was the same for each degree of shock.

1. The effect of different periods of starvation

This section is concerned with the effect of a series of different starvation periods upon the behavior of the white rat in the obstruction-incentive situation. The effect of the different starvation periods will be considered when the obstruction involves (*a*) a low degree of electrical stimulation—shock 1; (*b*) a medium degree—shock 2; and (*c*) a high degree—shock 3.

The effects of the different periods of starvation will be discussed in respect to five main types of data. First, in relation to the number of crossings made by each group, as indicated by the

TABLE 5

Results of different starvation groups under shock 1

STARVATION PERIOD	CROSSINGS									CONTACTS				JUMPS			
	Median	Average	Standard deviation	Coefficient of variability	Range	Per cent immediately conditioned	Per cent crossing 5 times or less	Per cent crossing 40 times or more	Per cent not conditioned	Median	Average	Standard deviation	Coefficient of variability	Median	Average	Standard deviation	Coefficient of variability
Control group..	1.6	1.7	2.5	153	0–12	60	95	0	0	2.0	1.6	0.97	61	0.66	1.1	2.34	213
12 hours.....	4.5	17.2	23.3	135	0–77	33	55	19	11	4.6	4.5	3.10	69	2.4	3.3	5.28	160
24 hours.....	28.6	29.1	22.3	77	0–98	13	25	33	18	1.9	2.3	2.32	101	5.0	4.7	4.26	91
36 hours.....	37.0	41.6	25.4	61	0–89	5	10	50	50	3.7	3.2	2.42	76	3.8	5.2	7.01	136
48 hours.....	27.0	30.7	19.6	64	5–80	0	5	33	30	2.6	2.7	2.37	89	1.0	2.2	3.97	179
60 hours.....	6.7	11.8	14.7	124	1–58	9	46	9	23	3.1	2.8	1.99	71	3.6	4.7	4.89	104
*	4.6	10.1	14.2	140	0–58	22	54	7	19								
72 hours.....	16.5	18.0	15.8	88	2–68	0	24	5	33	2.4	2.0	1.0	51	1.4	2.3	3.24	141
*	2.0	9.5	14.6	154	0–68	48	60	25	17								

A crossing indicates that the animal passed over the grill into the incentive compartment. A contact involves merely touching the grill and refusing to cross, or if partially across, turning back into the entrance compartment. Jumps occurred in the entrance compartment and involved clearing the floor with all four feet.

* Results in this row include the dead.

TABLE 6

Results of different starvation groups under shock 2

STARVATION PERIOD	CROSSINGS									CONTACTS				JUMPS			
	Median	Average	Standard deviation	Coefficient of variability	Range	Per cent immediately conditioned	Per cent crossing 5 times or less	Per cent crossing 40 times or more	Per cent not conditioned	Median	Average	Standard deviation	Coefficient of variability	Median	Average	Standard deviation	Coefficient of variability
Control group..	2.4	5.3	9.4	177	1–36	35	85	0	0	1.6	1.3	1.12	90	1.7	2.4	3.13	133
12 hours.....	3.3	9.3	18.4	198	0–108	30	65	5	5	2.9	2.4	2.17	90	0.87	1.4	2.47	174
24 hours.....	2.6	12.4	19.9	160	0–74	40	67	15	5	2.9	3.0	2.41	80	2.5	3.3	3.89	119
36 hours.....	3.5	9.4	15.6	166	0–60	28	75	10	8	3.3	3.2	1.77	56	1.1	1.8	4.49	249
48 hours.....	20.0	22.5	20.0	89	0–77	18	38	25	38	3.4	3.7	3.54	96	2.0	3.7	6.37	175
60 hours.....	4.1	9.4	12.2	131	0–46	18	68	2.5	0	2.6	2.4	1.60	66	1.2	1.8	2.96	169
72 hours.....	6.0	10.9	11.6	111	0–50	19	43	4.8	10	3.6	3.7	2.57	70	0.89	2.5	3.81	155
*	0.0	2.5	9.7	389	0–50	61	73	2.3	5								

See legend accompanying table 5.

TABLE 7

Results of different starvation groups under shock 3

STARVATION PERIOD	CROSSINGS									CONTACTS				JUMPS			
	Median	Average	Standard deviation	Coefficient of variability	Range	Per cent immediately conditioned	Per cent crossing 5 times or less	Per cent crossing 40 times or more	Per cent not conditioned	Median	Average	Standard deviation	Coefficient of variability	Median	Average	Standard deviation	Coefficient of variability
Control group..	2.3	5.6	11.8	210	0–54	45	80	5	5	1.7	1.4	1.14	81	2.5	5.2	7.49	144
12 hours.....	3.2	6.8	10.8	159	0–44	18	75	2.5	0	2.3	2.0	1.80	89	2.8	4.2	5.08	122
24 hours.....	8.0	20.0	24.3	122	0–93	20	25	23	0	2.8	2.5	1.82	72	1.8	2.6	3.22	124
36 hours.....	5.5	14.1	18.2	129	0–79	23	53	10	0	3.5	3.6	2.40	67	3 6	3.8	3.51	92
48 hours.....	4.3	11.0	16.6	151	0–70	33	68	7.5	0	2.6	2.4	1.84	77	2.5	4.3	6.01	141
60 hours.....	6.3	10.6	13.5	127	0–69	20	48	2.5	0	3.2	3.4	3.69	109	3.0	4.5	5.13	114
*	2.6	8.0	12.6	158	0–69	40	60	2	0								
72 hours.....	7.5	14.8	16.3	110	0–70	14	41	8.1	0	3.6	3.2	2.18	69	2.2	3.9	5.17	133
*	3.7	11.2	15.5	138	0–70	35	55	6.1	0								

See legend accompanying table 5.

TABLE 8

Showing the reliability of the difference between the various starvation periods (average crossings) under shock 1

STARVATION GROUP	12		24		36		48		60		72	
	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$
Control	3.87	4.03	3.57	7.70	4.06	9.85	3.15	9.23	2.55	3.33	2.38	3.31
12			5.21	2.27	5.55	4.40	4.93	2.73	4.57	1.55	4.48	1.72
24					5.34	2.34	4.70	0.09	4.31	4.40	4.22	4.64
36							5.07	2.15	4.59	6.49	4.63	6.93
48									3.81	5.41	3.87	5.48
60											3.20	0.19

TABLE 9

Showing the reliability of the differences between the various starvation periods (average crossings) under shock 2

STARVATION GROUP	12		24		36		48		60		72	
	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$
Control	3.59	0.90	3.82	1.83	3.23	1.27	3.80	4.52	2.85	1.43	2.56	1.09
12			4.31	0.72	3.80	0.03	4.30	3.07	3.49	0.03	3.26	2.08
24					4.02	0.75	4.49	2.24	3.72	0.81	3.51	2.82
36							4.00	3.28	3.12	0.00	2.85	2.42
48									3.70	3.54	3.48	5.74
60											2.42	2.85

TABLE 10

Showing the reliability of the difference between the various starvation periods (average crossings) under shock 3

STARVATION GROUP	12		24		36		48		60		72	
	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$
Control	3.14	0.38	4.66	3.09	3.90	2.17	3.72	1.45	3.16	0.76	2.81	1.63
12			4.20	3.14	3.35	2.18	3.13	1.34	2.43	0.49	2.80	1.57
24					4.80	1.22	4.65	1.93	4.21	2.85	4.42	1.98
36							3.89	0.80	3.36	1.81	3.63	0.80
48									3.14	0.96	3.43	0.06
60											2.81	1.13

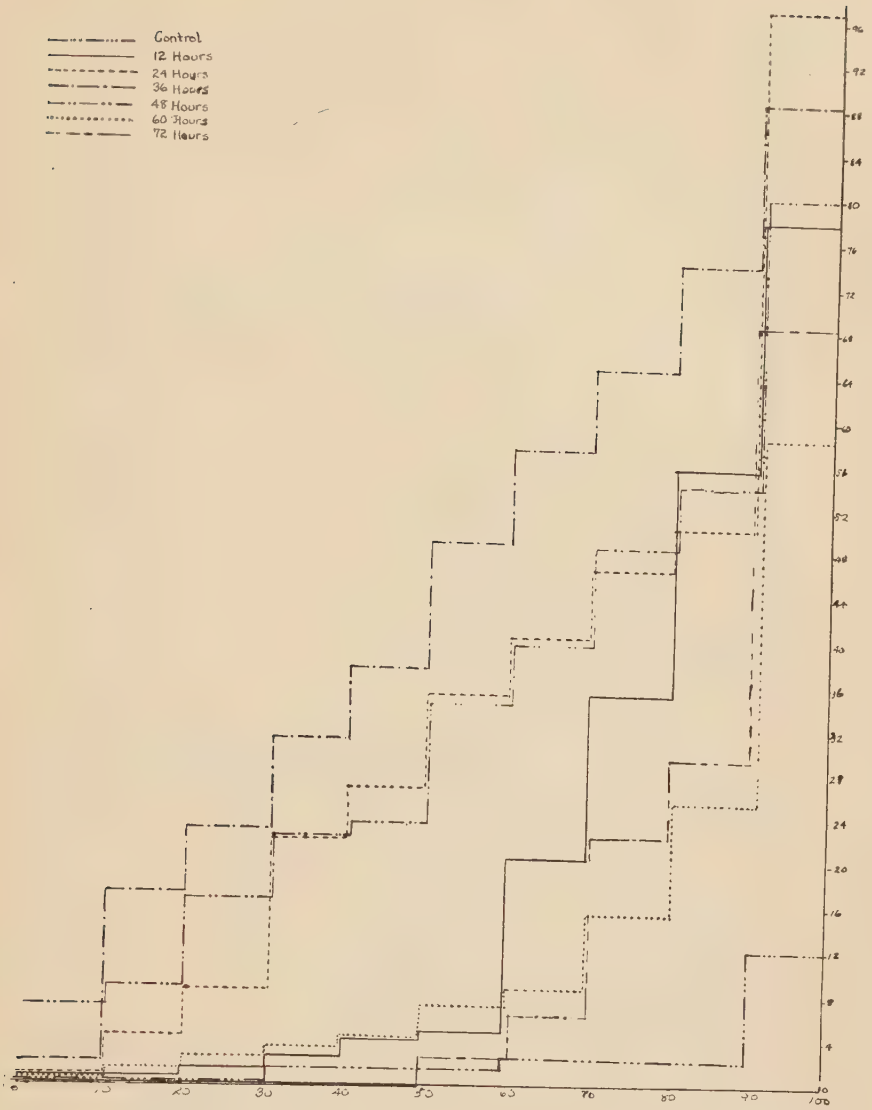

FIG. 2. PERCENTILE DISTRIBUTION OF EACH STARVATION GROUP COVERING CROSSINGS WITH SHOCK 1

Ordinates indicate the number of crossings, abscissas the deciles of each distribution.

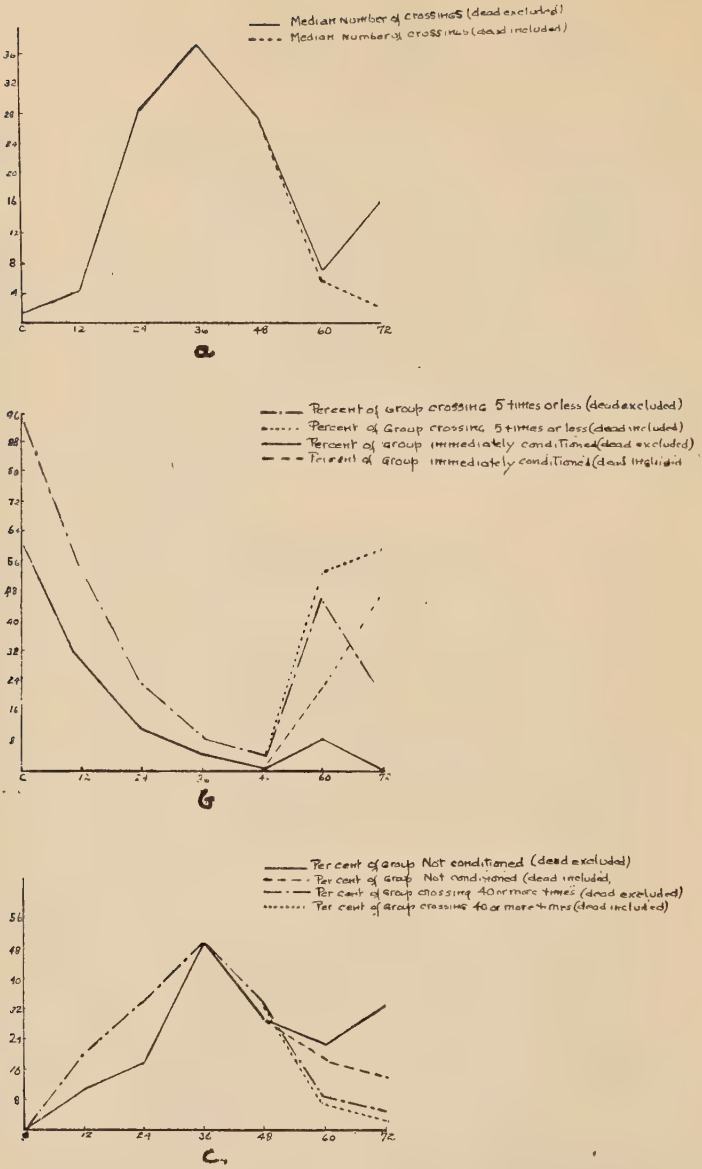
Median Number of crossings (dead excluded)
Median Number of crossings (dead included)
a
Percent of group crossing 5 times or less (dead excluded)
Percent of Group crossing 5 times or less (dead included)
Percent of group immediately conditioned (dead excluded)
Percent of Group immediately conditioned (dead included
b
Per cent of group Not conditioned (dead excluded)
Per cent of Group Not conditioned (dead included,
Per cent of group crossing 40 or more times (dead excluded)
Per cent of group crossing 40 or more times (dead included)
c.

FIG. 3

a. Showing median number of crossings made by each starvation group. Ordinates indicate number of crossings, abscissas periods of starvation.

b. Showing percentage of animals immediately conditioned and percentage crossing 5 times or less in each starvation group. Ordinates indicate percentages, abscissas periods of starvation.

c. Showing percentage of animals crossing 40 times or more and percentage that failed to be conditioned in each starvation group. Ordinates indicate percentages, abscissas periods of starvation.

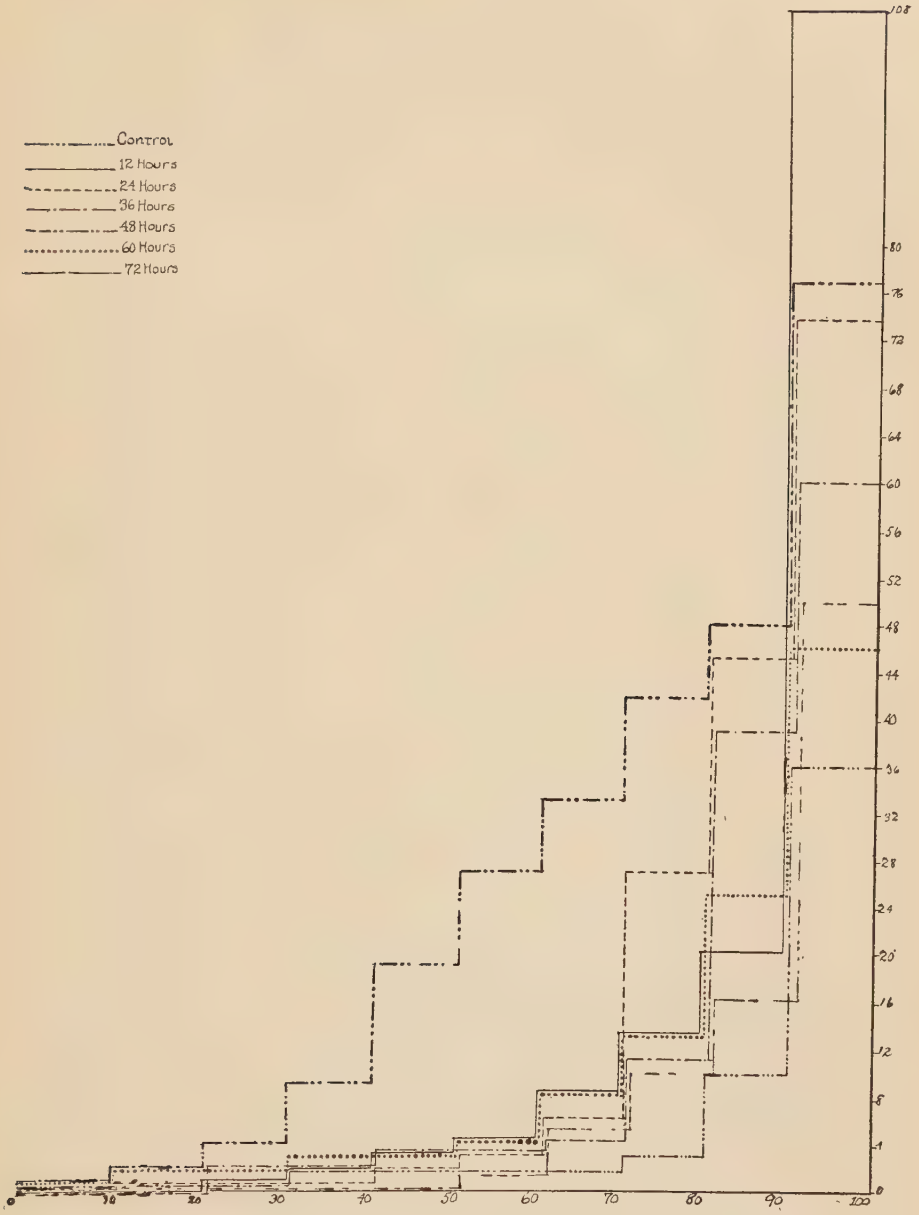

FIG. 4. PERCENTILE DISTRIBUTION OF EACH STARVATION GROUP COVERING CROSSINGS WITH SHOCK 2

Ordinates indicate the number of crossings, abscissas the deciles of each distribution.

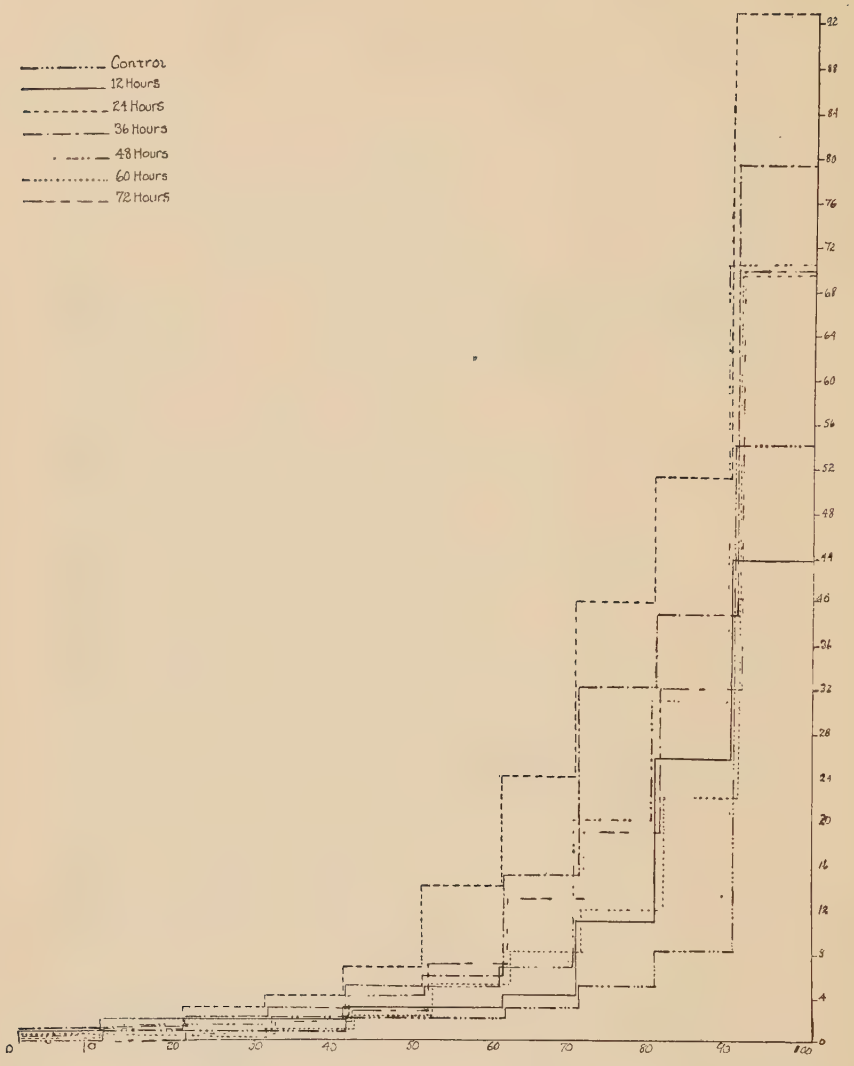

FIG. 5. PERCENTILE DISTRIBUTION OF EACH STARVATION GROUP WITH SHOCK 3 COVERING CROSSINGS

Ordinates indicate the number of crossings, abscissas the deciles of each distribution.

FIG. 6. SHOWING THE MEDIAN NUMBER OF CROSSINGS MADE BY EACH STARVATION GROUP WITH EACH DEGREE OF SHOCK

Ordinates indicate the number of crossings, the abscissas number of hours starvation

median,[4] or by the per cent of animals within each group that crossed the grill 40 or more times; or more fully by a comparison of the cumulative percentile graphs showing the distribution of each group in regard to the number of crossings. Second, by the per cent of animals within each starvation group that were immediately conditioned, i.e., that failed to cross the grill after the first experience with the shock. This figure probably indicates the number of animals in which the hunger drive was at the outset weaker than the resistance offered by the grill. Third, by the percentage of rats that failed to be conditioned within each group, i.e., were still crossing the grill at the end of the ten minute-test period. This figure probably indicates the number of animals in which the hunger drive was at the end of the test period still stronger than the resistance offered by the grill. Fourth by the median number of contacts and fifth by the median number of jumps made by each starvation group.

Shock 1. The results of the control group considered by any of these measures indicate that the tendency to cross the grill with shock 1, in the absence of the food incentive is negligible, the median number of crossings in this case being 1.6, while only 1 rat crossed the grill more than 3 times (table 5, row 1). In general the tendency to touch the grill and withdraw is greater than that of crossing it.

The number of crossings for the 12-, 24- and 36-hour groups increases with the length of the starvation period. When this period is increased beyond 36 hours there is a consistent decrease in the number of crossings. This holds true of the 72-hour group only if the dead are included in the results as failing to cross the grill.[5] When the dead are excluded, however, the number of

[4] The median rather than the average will be referred to throughout this discussion. Owing to the fact that the extreme deviations always occurred at the same end of the distribution scale, the average does not in this case give a reliable measure of central tendency.

[5] The results of the groups in which rats died of starvation are stated in tables 5, 6 and 7 both excluding and including the dead. Neither of these measures are entirely satisfactory for a direct comparison with the results of the other groups, but it is probable that the results in which the dead are included give a better measure of the tendency of the group than those which exclude them. This is

crossings made by the 72-hour group is greater than that for the 60-hour group. These results are clearly indicated by the medians of each group (table 5, column 1) and are shown graphically in figure 3, a. The results of the 24-hour group are in this respect approximately the same as those of the 48-hour group, while those of the 12-hour group are similar to those of the 60-hour group.

The relative effect of the different starvation periods as shown by the percentage of rats crossing 40 or more times (table 5, column 9) is similar to that shown by the median number of crossings with the exception that the number of animals crossing very frequently is greater in the 12 than in the 60-hour group (see fig. 3, c).

The variability of the different starvation groups (crossings—table 5, column 5) is in general inversely related to the strength of the drive. In the control group in which the hunger drive appears to be a negligible factor, the variability is extremely large (C.V. 153). With the series of starvation groups the variability is in every case smaller than with the control group. In general the variability tends to diminish as the starvation period is increased to 36 hours and to increase with the longer periods.

The distribution covering the crossings for each of the starvation groups is shown in figure 2 by means of cumulative percentile graphs. It is apparent from this figure that the differences between the starvation groups indicated above by the median and per cent crossing 40 or more times holds true between the corresponding deciles of each group. The differences between the control group and any of the starvation groups are immediately apparent. The fourth decile of the 12-hour, the second decile of the 24-hour, and the first decile of the 36-hour groups show as frequent crossings as the ninth decile of the control group. The 12- and 60-hour groups are similar throughout the first 6 deciles of their distributions, but from the sixth through the tenth deciles

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due to the fact that the dead in all probability correspond to the least active rats in the other groups. Consequently any results excluding them probably indicate only the tendencies of the upper end of the distribution scale.

the 12-hour group shows more frequent crossings than the 60-hour group. The distributions of the 24- and 48-hour groups are similar from the fourth through the ninth deciles, but from the first through the third decile the 48-hour group crossed considerably more frequently than the 24-hour group. In the tenth decile the 24 crossed more frequently than the 48-hour group. From the second through the ninth decile the 36-hour group crossed more frequently than any of the other groups. These results again indicate the similarity of the 12- and 60-hour groups but further emphasize the fact that the more active animals of the 12-hour group cross more frequently than those of the 60-hour group. It is also shown that the least active animals of the 48-hour group cross considerably more frequently than those of the 24-hour group although the results of these two groups are otherwise very similar.

The same results considered in relation to the percentage of rats that failed to cross the grill after their first experience with the shock, i.e., were immediately conditioned (table 5, column 7) indicate that increases in the period of starvation from 12 to 48 hours result in corresponding decreases in this type of behavior. After a starvation period of 48 hours all the rats crossed the grill at least 5 times. The results of further increases in the period of starvation, in this respect, cannot be determined because of the large proportion of animals that died in the 60- and 72-hour groups. Within these two groups all the living animals crossed at least once while in the 72-hour group no rat crossed less than 2 times. These results may indicate that the hunger drive of rats starved from 48 hours to the point of physical exhaustion is after the first experience with the shock still stronger than the resistance offered by the grill. The percentages of rats crossing the grill 5 times or less (table 5, column 8) give results similar to the percentages immediately conditioned for starvation periods of 12 to 48 hours (see fig. 3, b). With starvation periods of 60 and 72 hours, however, this measure seems to indicate that in many cases the hunger drive tends to become weaker than the resistance offered by the grill after 5 experiences with the shock. This appears to to be more often the case with the 60- hour than with the 24-, 36-, or 48-hour groups.

The percentage of rats that failed to be conditioned indicates that the hunger drive is strongest with the largest proportion of any group at 36 hours, since with this period of starvation 50 per cent of the group failed to be conditioned after 10 minutes experience with the shock, i.e., were still crossing the grill at the end of the test period. From this fact it might be concluded that the motivation resulting from 36 hours starvation is equivalent for this group to the resistance offered by 10 minutes experience with the grill under the conditions of this experiment. A further increase in the period of starvation to 48 hours reduced the number of animals that failed to be conditioned to 30 per cent. Further increases in the starvation period, however, do not appreciably alter this percentage. The number of rats failing to be conditioned in any group starved longer than 36 hours, is in every case, greater than that of any group starved less than 36 hours (see fig. 3, c).

From these results it appears that, measured by the number of crossings, the hunger drive tends to increase in strength as the period of starvation is increased from 12 to 36 hours and to decrease as it is further increased from 36 to 72 hours. It is probable, however, that any determination of these results in terms of the number of times the grill was crossed measures not only the hunger drive but also the factor of general activity since physical exhaustion necessarily results from long starvation periods. As has been stated above the tendency to cross the grill very frequently is considerably greater with the 12- than with the 60-hour group, whereas the tendency to persist in attempts to reach the food stimulus, as shown by the per cent of each group that failed to be conditioned and the per cent immediately conditioned, is considerably greater with the 60- than with the 12-hour group. As indicated by the number of times the grill was crossed the hunger drive appears to diminish from a maximum at 36 hours to the point of physical exhaustion which occurred with the majority of these rats after 72 hours starvation. However a rat that was too weak to cross the grill still made attempts to do so, thus indicating that the hunger drive had not been entirely overcome, even though extreme physical exhaustion had set in. Conse-

quently the number of crossings within the test period does not measure the hunger drive alone but also includes the factor of general bodily activity. Richter (9) found that the general activity of the white rat increases with the period of starvation, reaching a maximum at between 2 and 3 days, and then continuously decreases to the point of physical exhaustion at 8 days. Richter's results would appear similar to those obtained in the present study when measured in terms of the number of times the grill was crossed by each group. It is probable therefore that with the longer hunger periods (48 to 72 hours) this measure indicates the physical capacity of the rats to attain the incentive stimulus rather than the actual motivation resulting from this stimulus. The latter factor is probably better indicated by the percentages of animals immediately conditioned and failing to be conditioned, since these measures are based upon persistence in reaching the food stimulus even when the physical capacity to do so is relatively slight.

Considering these results together it appears that the hunger drive reaches a maximum strength at 36 hours. After 48 hours this drive seems to be slightly diminished, but further increases in the length of the starvation period to 60 and 72 hours do not seem to result in any further weakening of the hunger drive, although the capacity to reach the stimulus is greatly reduced owing to the onset of physical exhaustion.

The reliability of the differences in crossings between any two groups in the shock 1 series will be found in table 8. It is apparent that the differences between any starvation group and the control group are completely reliable. The differences between the 12- and 36-hour groups and between the 36- and 60- or 72-hour groups are also extremely reliable. The differences between the 12- and 24-, or between the 24- and 36-hour groups are less reliable as are also the differences between the 36- and 48-, or that between the 48- and 60-hour groups.

The tendency to touch the grill without crossing as indicated by the median number of contacts made by each group (table 5, column 11) does not appear to be related directly to the length of the starvation period. The tendency to touch the grill is great

with the 12- and 60-hour groups in which the contacts tended to deter the rats from further crossings. It was also large with the 36-hour group, but in this case the contacts generally immediately preceded the crossings and were not as effective in conditioning as in the other groups. The tendency to jump was in general greater with starvation periods of 36 hours or less than with the longer periods.

Shock 2. The results of the shock 2 series are difficult to interpret because of the lack of consistent tendencies. These results seem to indicate that the shock used in this series was so great as to arouse drive factors other than those of hunger. Some animals appeared to be reacting against the electric grill in section *B* rather than to the food stimulus in section *C*. After rushing across the grill into section *C* they did not eat but sat in a corner with sides palpitating as if in fear, or attempted to jump from the box. Apparently they did not discriminate between sections *A* and *B* for upon being replaced in *A* after crossing they would immediately dash across the grill.

The type of reaction thus described was evident in the control group, as shown by the fact that 15 per cent of the animals crossed between 10 and 36 times, in spite of the fact that section *C* contained no food. The median number of crossings (2.4), however, indicates that the majority of these animals were easily conditioned.

The differences between the control group and any of the starvation groups in this series, with the exception of the 48-hour group, are too small to be reliable. The median number of crossings of the control, 12-, 24-, 36-, and 60-hour groups all fall between 2.4 and 4.1. The median number of crossings is 6.0 for the 72-hour group excluding the dead and 0.0 when they are included. The percentage of animals crossing the grill 40 or more times is not large with shock 2; the largest number (25 per cent) occurred in the 48-hour group. The tendency to cross the grill continuously is slightly greater with the 24- and 36-hour than with the 60- and 72-hour groups. The greatest differentiation between the groups is shown by the percentage of animals that were immediately conditioned (table 6, column 7). The results

of the control, 12-, and 24-hour groups are quite similar in this respect ranging from 30 to 40 per cent. There is a decrease, however, to 28 per cent with the 36-hour group and to 18 per cent with both the 48- and 60-hour groups and to 19 per cent with the 72-hour group. The number of animals that failed to be conditioned (table 6, column 10) never rises above 15 per cent in any but the 48-hour group in which 38 per cent were still crossing the grill at the end of the test period.

The variability (crossings) of the 12-, 24-, and 36-hour groups (table 6, column 5) is very great ranging from 160 to 198. With the 48-hour group it falls to 89 and with the 60-hour group to 131.

In general it may be said that the individual differences between the animals of each group are so great as to obliterate any group differences that might result from the various starvation periods. It was observed that each group included both animals that regularly ate after crossing and animals that failed to do so. In the latter case the escape reaction was evident. Upon being returned to section *A* these rats either withdrew as far as possible from the grill making no further attempt to cross, or immediately recrossed. In the latter case the crossings occurred in rapid succession and then ceased altogether. In the former case there were frequent pauses between crossings and the animals gave no indications of fear.

The cumulative percentile graph (fig. 4) for shock 2 indicates clearly the difference between the 48-hour and the other groups of this series. The tendency to cross the grill in the 48-hour group is evident in the fourth decile and very marked from the fifth through the tenth decile. The majority of the animals in this group ate after crossing the grill and showed little evidence of fear. They seemed to be reacting directly to the food stimulus rather than attempting to escape. Pauses within section *A* and contacts followed by withdrawal without crossing were frequent in this group. This type of reaction, shown by the majority of the 48-hour group, occurred in only a few cases in the other groups of this series. The tendency to cross the grill is very slight with any other group. In fact from the first through the sixth decile the number of crossings made by any starvation group other than the 48-hour differs only slightly from that of the control group.

In the ninth and tenth deciles the tendency toward extreme reactions is considerable and greater in every case with the starvation groups than with the control group. This fact, however, does not warrant the conclusion that these extreme reactions were due to the hunger drive alone, since in many cases the animals failed to eat after each crossing, although given ample opportunity to do so.

It appears from these results that the 48-hour group is the only one of the shock 2 series in which the strength of the hunger drive is at all comparable with the resistance offered by the grill. Throughout the other groups this shock appears to disturb seriously the hunger drive of the majority of the animals. This disturbance seems to be greater with groups that have been starved less than 36 hours than with those starved more than 36 hours, inasmuch as the number of animals immediately conditioned is considerably less with the longer starvation periods. This fact considered in conjunction with the results of the 48-hour group above discussed suggests that the degree of shock sufficient to overcome the hunger drive (as indicated by a failure to react to the food stimulus when in the presence of it) is not identical for all periods of starvation but is dependent upon the length of the starvation period preceding the shock.

The tendency to touch the grill without crossing in the shock 2 series appears to bear some relation to the length of the starvation period although the differences between the groups are not large. The number of contacts made by each starvation group is in every case twice as great as the number made by the control group. The median number of contacts (table 3, column 11) increases from 2.9 with the 12-hour group to 3.4 with the 48-hour group and falls to 2.6 with the 60-hour group. Jumping behavior seems to bear no consistent relation to length of starvation period under the conditions of shock 2. The number of jumps (table 3, column 15) is greatest with the 24-hour group and slightly smaller with the 48-hour group, but the other groups do not differ greatly from the control group in this respect.

Shock 3. The tendency to react against the grill rather than to the food stimulus is noticeable to a much greater extent with

shock 3 than with shock 2. The results of the control group (crossings) of this series are extremely variable (C.V. 210), and seem to indicate that a strong degree of shock results with a few animals in a decided tendency to cross the grill. The only rat that failed to be conditioned by shock 3 occurred in the control group, in the absence of any food stimulus. This rat showed evidence of fear and seemed to be fleeing from section *A*.

The tendency to cross the grill with shock 3 is relatively slight except in a few extreme cases. Every rat in each starvation group was conditioned against the grill by shock 3 within the test period (table 7, column 10). The greatest tendency to cross the grill frequently, as shown by the percentage of animals crossing 40 or more times (table 7, column 9) occurred in the 12- and 24-hour groups. With the other groups this tendency does not differ noticeably from that of the control group. The median number of crossings (table 7, column 2) increases from 2.3 with the control group to 8.0 with the 24-hour group and then falls to 4.3 as the period of starvation is increased to 48 hours. The effect of a 60- and 72-hour starvation period upon the shock 3 groups cannot be determined owing to the fact that so many animals in these groups died. If the dead are excluded from the results these groups appear to cross the grill more frequently than the 48-hour group, whereas if they are included the medians are smaller than that of this group. The percentage of rats immediately conditioned and the percentage crossing the grill 5 times or less (table 7, columns 7 and 8) show the same trend as the median number of crossings.

The percentile graph for shock 3 (fig. 5) indicates that the difference between the various starvation groups from the first through the fifth decile is negligible. Moreover there is no apparent difference between the starvation and control groups within this range. From the sixth through the tenth decile, however, the 24-hour group crosses more frequently than any of the other groups, while from the seventh through the tenth decile the 36-hour rats cross more frequently than those of any group with the exception of the 24-hour. Since the differences between the control and starvation groups (excepting the 24-hour

group) are very small and unreliable, and since animals usually failed to eat after crossing, shock 3 cannot be said to offer a measure of the hunger drive alone. That some factor other than the incentive stimulus operates with shock 3 is shown by the fact that animals crossed frequently in the absence of food and after refusing to eat. This additional factor appears to be the tendency to escape, which is stimulated by the shock itself and results from an association of the grill with section *A*. The fact that the number of crossings increases with an increase in the starvation period from 12 to 24 hours and decreases with further increases from 24 to 48 hours indicates that there is some relation between the tendency to cross the grill and the length of the starvation period. This relation is probably due to differences in the organic state of the animals resulting from the different starvation periods. Richter (supra) found that general activity bore a direct relation to differences in organic state resulting from different starvation periods. Consequently it is probable that shock 3 indicates more clearly the factor of general activity than the motivation resulting directly from the incentive stimulus.

The median number of contacts in this series increases from 2.3 with the 12-hour group to 3.5 with the 36-hour group and then decreases to 2.6 with the 48-hour group. There appears to be an increase in the number of contacts with the 60- and 72-hour groups but owing to the number of deaths in these groups, the results are not comparable with the others of this series. The jumping activity (table 7, column 15) shows no relation to the length of the starvation periods. It is rather large in every instance but that of the 24-hour group.

2. The effect of different degrees of electrical stimulation

This section is concerned with the effect of different degrees of electrical stimulation upon drive behavior resulting from a given starvation period. The relative effect of the three degrees of shock upon the control group and upon each of the six starvation periods will be considered, as measured by crossings, contacts, and jumps.

Control group. In the absence of a food stimulus in section *C*,

TABLE 11

Showing the effect of different degrees of shock upon the same starvation group

	CROSSINGS							CONTACTS (MEDIAN)	JUMPS (MEDIAN)
	Median	Coefficient of variability	Range	Per cent immediately conditioned	Per cent crossing 5 times or less	Per cent crossing 40 times or more	Per cent not conditioned		
Control group									
Shock 1.....	1.6	153	0–12	60	95	0	0	2.0	0.66
Shock 2.....	2.4	177	1–36	35	85	0	0	1.6	1.7
Shock 3.....	2.3	210	0–54	45	80	5	5	1.7	2.5
12-hour group									
Shock 1.....	4.5	135	0–77	33	55	19	11	4.6	2.4
Shock 2.....	3.3	198	0–108	30	65	5	5	2.9	0.87
Shock 3.....	3.2	159	0–44	18	75	2.5	0	2.3	2.8
24-hour group									
Shock 1.....	28.6	77	0–98	13	25	33	18	1.9	5.0
Shock 2.....	2.6	160	0–74	40	67	15	5	2.9	2.5
Shock 3.....	8.0	122	0–93	20	25	23	0	2.8	1.8
36-hour group									
Shock 1.....	37.0	61	0–89	5	10	50	50	3.7	3.8
Shock 2.....	3.5	166	0–60	28	75	10	8	3.3	1.1
Shock 3.....	5.5	129	0–79	23	53	10	0	3.5	3.6
48-hour group									
Shock 1.....	27.0	64	5–80	0	5	33	30	2.6	1.0
Shock 2.....	20.0	89	0–77	18	38	25	38	3.4	2.0
Shock 3.....	4.3	151	0–70	33	68	7.5	0	2.6	2.5
60-hour group									
Shock 1.....	6.7	120	1–58	9	46	9	23	3.1	3.6
*	4.6	140	0–58	22	54	7	19.5	2.6	1.8
Shock 2.....	4.1	131	0–46	18	68	2.5	0	2.6	1.2
Shock 3.....	6.3	127	0–69	20	48	2.5	0	3.2	3.0
*	2.6	158	0–69	40	60	2	0	2.4	1.9
72-hour group									
Shock 1.....	16.5	88	2–68	0	24	5	33	2.4	1.4
*	2.0	154	0–68	48	60	2.5	17.5	0.0	0.0
Shock 2.....	6.0	111	0–50	19	43	4.8	10	3.6	0.89
*	0.0	389	0–50	61	73	2.3	5	0.0	0.0
Shock 3.....	7.5	110	0–70	14	41	8.1	0	3.6	2.2
*	3.7	138	0–70	35	55	6.1	0	2.6	0.0

* Results in this row include the dead.

the central tendencies of the groups indicated by the medians (table 11, column 1) are not materially affected by increasing the shock. The extreme tendencies of the groups are however considerably affected. The percentage of animals immediately conditioned by shock 1 is greater than that by either shocks 2 or 3. Frequent crossings of the grill increase directly with an increase in shock as shown by the fact that only one rat crossed the grill more than 3 times, and that only 12 times, with shock 1, whereas 3 rats crossed between 10 and 36 times with shock 2, and 3 between 8 and 54 times with shock 3. Moreover the only animal that failed to be conditioned in any control group occurred with shock 3. As indicated by the coefficient of variability an increase in shock directly increases the variability of the groups (table 11, column 2).

The number of contacts made by the control groups was greater with shock 1 than with either shocks 2 or 3 (table 11, column 8). This appeared to be due to the fact that the rats moved much more rapidly and less cautiously with shocks 2 and 3 and consequently upon touching the grill did not stop but proceeded across the grill, whereas with shock 1 the animals approached the grill rather slowly and generally withdrew after experiencing the shock. The number of jumps made by the control groups appears to be directly increased by an increase in shock, the median number of jumps being 0.66 with shock 1, 1.7 with shock 2, and 2.5 with shock 3.

In brief, in the absence of the food stimulus an increase in shock while affecting the central tendencies (crossings) of the groups only slightly produces a marked effect upon the extreme tendencies of the groups. The lowest degree of shock appears to be most effective in immediately deterring the animals from crossing the grill, whereas a heavy shock may result in repeated crossings. Inasmuch as the degree of shock constitutes the only variable condition in the control groups, it must be assumed that the increased tendency to cross the grill is due to the shock itself. Observations of the behavior of the animals indicated that an increase in the degree of shock used resulted in an increase in the reactions indicating fear. Such reactions were not evident with

shock 1 but occurred frequently with shock 2. In such cases the rats after crossing, ran wildly about section *C* or tried to jump from the box. Upon being replaced in section *A* they would dash immediately across the grill or bury their heads in a corner of the box, in which position they would remain, breathing very rapidly until finally removed. With shock 3 the number of animals showing these reactions was greater and the conditions described more exaggerated. Jumping also occurred more frequently with an increase in shock. From these facts it appears that in the absence of the incentive stimulus shocks 2 and 3 were both strong enough to frighten the animals. The increase in the

TABLE 12

Showing the reliability of the difference between the various shocks (average crossings) for a given starvation group

STARVATION GROUP	SHOCKS 1 AND 2		SHOCKS 2 AND 3		SHOCKS 1 AND 3	
	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$	SD_D	$\frac{D}{SD_D}$
Control	2.17	1.70	3.37	0.09	2.70	1.48
12	4.81	1.64	3.37	0.74	4.19	2.48
24	4.75	3.51	4.99	1.69	5.21	1.75
36	4.70	6.85	3.78	1.24	4.94	5.56
48	4.43	1.85	4.11	2.80	4.06	4.85
60	3.14	0.02	2.59	0.54	3.03	0.69
72	2.73	2.56	2.65	3.28	3.20	0.53

number of crossings made by some rats with an increase in shock seemed to be due to the fact that fear aroused random movements resulting in a failure to discriminate between sections *A* and *B* so that *A* was reacted to in the same way as *B*.

Twelve-hour group. With the introduction of the incentive stimulus in section *C* the relative effect of the three degrees of shock upon the behavior of the rats is changed. The differences between the central tendencies of the groups are, as with the control group, small and unreliable (table 12). An increase in shock in this case, however, appears to decrease the number of times the rats will cross the grill, the medians being 4.5 with shock 1, 3.3 with shock 2, and 3.2 with shock 3.

The results of the three degrees of shock in regard to immediate

conditioning indicate a somewhat different effect. Thirty-three per cent were immediately conditioned by shock 1, 30 per cent by shock 2, and 18 per cent by shock 3. Animals reacting to shock 3 are thus more likely to cross the grill at least twice than when the lighter shocks were used. On the other hand shock 3 is the most effective of the three shocks in finally conditioning the animals since no rats failed to be conditioned in this case, whereas 2.5 per cent remained unconditioned with shock 2 and 11 per cent with shock 1. Moreover only 25 per cent of the group crossed more than 5 times with shock 3, while 35 per cent did so with shock 2 and 45 per cent with shock 1. The number of rats crossing 40 or more times was also directly decreased by an increase in shock.

The number of contacts in the 12-hour group decreased with an increase in shock (table 11, column 8). The tendency to jump does not vary consistently with the degree of shock as will be seen from table 11.

While the control and 12-hour groups had been without food exactly the same length of time, the results are quite opposed in respect to the relative effect of the three degrees of shock. It will be recalled that in the control group the animals reacting to shock 1 showed the least tendency to cross the grill, while in the 12-hour group they show the greatest tendency to do so. Moreover whereas the greatest tendency to cross in the control group occurred with shock 3, in the 12-hour group this shock is most effective in deterring the rats from crossing.

Twenty-four-hour group. The difference between the results (crossings) with shocks 1 and 2 after a 24-hour period of starvation is large and reliable (table 12). The number of crossings made with shock 1 is considerable as shown by a median of 28.6 and the fact that 75 per cent of the group crossed more than 5 times. The tendency to cross with shock 2 is, on the other hand, very slight as shown by a median of 2.6 and the fact that only 23 per cent of this group crossed more than 5 times. Only 13 per cent of the animals used with shock 1 were conditioned immediately, while 40 per cent of the group with shock 2 were immediately conditioned.

The number of crossings made with shock 3 is in this case greater than with shock 2, but considerably less than with shock 1, the median number of crosses being 8.0. The tendency to cross 40 or more times with shock 3 was not quite as marked as with shock 1 as shown by the fact that 23 per cent of the group with shock 3 crossed 40 or more times whereas 33 per cent did so with shock 1. The number of rats immediately conditioned by shock 3 is only half as great as that by shock 2.

The results of the 24-hour group are least variable with shock 1 and most variable with shock 2 (table 11, column 2).

The number of contacts made by the 24-hour groups was smallest with shock 1. The number of jumps in this case decreased directly with an increase in shock.

The behavior of the rats in response to the food after crossing to section *C* varied considerably with the different shocks. With shock 1, the rats ran immediately to the food and started eating with all possible speed. With shock 2 some rats reacted in like manner showing practically no evidence of fear, while others were obviously frightened and paid no attention to the food, but tried to jump out of section *C*. With shock 3 hardly any of the animals noticed the food. They either cowered in a corner of section *C* or attempted to jump from the box. The speed in crossing the grill when replaced in section *A* also differed with the different shocks. With shock 1 hesitation for several seconds at the edge of the grill followed by a crossing, frequently occurred, whereas with shock 3, if they crossed at all, the tendency was to dash immediately across the grill after being placed in *A*. Very little hesitation at the edge of the grill occurred with shock 2 although the temporal interval between crossings varied considerably from rat to rat.

Thirty-six-hour group. The relative effect of the three degrees of shock upon crossings with the 36-hour group is in general similar to that noted with the 24-hour group. The largest number of crossings was made with shock 1 (median 37.0) and the smallest number with shock 2 (median 3.5). The difference between the results with shocks 1 and 2 is in this case extremely reliable (table 12). The number of crossings made with shock 3 (median 5.5) is slightly greater than that with shock 2.

The number of animals that failed to be conditioned is largest with shock 1 (50 per cent), while none failed to be conditioned by shock 3. The number of rats immediately conditioned was again smallest with shock 1 (5 per cent) and greatest with shock 2 (28 per cent).

The number of contacts made with shock 1 was rather large (median 3.7). In this case, however, a contact was generally a preliminary reaction immediately preceding a crossing. With shocks 2 and 3 the contacts did not bear as close a relation to the crossings but were only slightly less frequent than with shock 1. Jumping activity was considerable with shocks 1 and 3 but was relatively slight with shock 2.

Forty-eight-hour group. With the 48-hour group the tendency to cross the grill is directly related to the degree of shock. The group with shock 1 crossed most frequently (median 27.0) and that with shock 3 least frequently (median 4.3). The number of crossings with shock 2 was in this case only slightly less (median 20.0) than with shock 1. With shock 1, however, only 5 per cent crossed 5 times or less whereas 38 per cent did so with shock 2 and 68 per cent with shock 3. The number of rats failing to be conditioned was slightly greater with shock 2 than with shock 1, but the number crossing 40 or more times was slightly less than with shock 1.

The number of contacts was approximately the same with shocks 1 and 3 (medians 2.6) but slightly greater with shock 2 (median 3.4). The jumping activity increased directly with an increase in shock.

The variability (crossings) of the 48-hour group is least with shock 1 and greatest with shock 3 (table 11).

Sixty-hour group. Due to the fact that some of the 60-hour rats, with shocks 1 and 3, died, the results for the three degrees of shock are not entirely comparable. The general effect of an increased shock appears, however, to be very slight with the 60-hour group. Considering these results in terms of the medians the differences between the groups are negligible and have no reliability. The variability of the three groups is approximately the same (table 11, column 2).

If the results are considered in respect to the percentage of animals that were immediately conditioned, there appears to be a slightly greater tendency for all the rats to cross with shock 1 than with shocks 2 or 3. More rats crossed 5 times or less with shock 2 than with shocks 1 or 3. The chief difference between the 3 degrees of shock occurs at the upper end of the scale as 9 per cent of the group with shock 1 crossed 40 or more times whereas only 2.5 per cent did so with shocks 2 and 3. 23 per cent of the group with shock 1 failed to be conditioned while none failed to be with shocks 2 and 3.

The number of contacts is relatively large with shocks 1 and 3 (medians 3.1 and 3.2, respectively) but is somewhat less with shock 2 (median 2.6). The tendency to jump is also considerably greater with shocks 1 and 3 (medians 3.6 and 3.0) than with shock 2 (median 1.2).

It appears from these results that an increase in shock with rats that have been starved 60 hours was only effective in respect to the animals that crossed the grill most frequently, since an increase in shock diminished the number of extreme cases but did not noticeably affect the central tendency. In general, the activity shown by touching the grill and jumping was greater with shocks 1 and 3 than with shock 2.

Seventy-two-hour group. With these groups the factor of selection is again operative so that the results are not entirely comparable. In general the tendency to cross the grill is greatest with shock 1 since no animals were immediately conditioned in this case whereas 19 per cent were by shock 2 and 14 per cent by shock 3. The percentage of rats crossing 5 times or less is also smaller with shock 1 than with shocks 2 or 3. The number crossing 40 or more times is approximately the same with the three degrees of shock, but the number failing to be conditioned decreased directly with an increase of shock. As shown by the median the number of crossings was greatest with shock 1 and considerably less with shocks 2 and 3 (table 11).

In general the number of contacts is greater with shocks 2 and 3 than with shock 1. The number of jumps in this case seems to bear no relation to the degree of shock.

Summary. The results of the three degrees of shock upon the same starvation periods show that, in the absence of the incentive stimulus, the tendency to cross the grill is relatively slight with any degree of shock. In this case, however, the general tendency of an increased shock, as has been stated in the discussion of the control group, is to increase the tendency to cross the grill. This fact indicates that a strong shock in itself produces a certain degree of motivation.

These results show that when the food stimulus is introduced into the otherwise identical situation the relative effect of the three degrees of shock was dependent upon the length of the starvation period that had preceded the shock. The relative effect of the three degrees of shock on each starvation group can be clearly observed in figure 6. With either a short (12 hours) or long (60 and 72 hours) starvation period the tendency to cross the grill is not markedly different with the three degrees of shock, although there is a slight tendency to cross more frequently with shock 1 than with shocks 2 or 3, except in the case of the 72-hour groups where the results of the three degrees of shock are not comparable owing to the deaths occurring in these groups. With a median period of starvation (24 or 36 hours), however, the number of crossings made with shock 1 is very great, but is relatively slight with shocks 2 and 3. With these shocks the tendency to cross the grill in response to the food stimulus does not appear to differ radically from that observable when the food stimulus is absent. This fact indicates that shocks 2 and 3 do not give adequate measures of the relative effect of different periods of starvation. Shock 2 appears to divide the animals into two groups, those motivated largely by the food stimulus and those motivated chiefly by fear. With shock 3 the fear motivation appeared to become dominant in practically all cases. With shock 1, however, all the animals seemed to be motivated by the food stimulus. Consequently the data of shock 1 alone, can be considered as affording measures of the hunger drive.

IV. SUMMARY AND CONCLUSIONS

1. Of the three degrees of electrical stimulation used in compartment *B* as an obstruction against which to measure the hunger drive, only the lowest proved to be suitable for use with this method. Both of the higher shocks were severe enough to disturb the normal food response. Shock 2, in general, had the effect of separating the animals of each starvation group into two classes: in one case the animals appeared to be motivated mainly by hunger and in the other mainly by fear. Shock 3 was so severe that it seemed to introduce an additional source of motivation which disturbed and obscured the normal hunger drive.

2. The lowest degree of shock furnished a degree of stimulation adequate for the measurement of the hunger drive by the Obstruction Method, in that it was high enough to bring out differentiation in drive behavior resulting from different periods of starvation, and low enough not to arouse other conflicting tendencies.

Inasmuch as shock 1 alone proved suitable with this method for the measurement of the hunger drive the following statements are based solely on data obtained with this shock.

3. As measured by the number of crossings within the test period, the hunger drive appears to increase from 12 to 36 hours and to decrease with further increases in the length of the starvation period.

4. The hunger drive as indicated by the percentage of animals immediately conditioned and by that failing to be conditioned, apparently reaches its maximum at 36 to 48 hours and remains fairly constant from this point to 72 hours.

5. As measured by the number of crossings the results of the 24- and 48-hour drives appear to agree, while the 12- and 60-hour drives have highly similar values. As indicated by the per cent that failed to be conditioned, however, the hunger drive, is stronger with a 48- and 60-hour starvation period than with 12- and 24-hour periods. The difference between the results of these two measures is probably in large part due to the factor of physical exhaustion occurring with the longer starvation periods.

6. The number of contacts and jumps do not appear to bear any consistent relation to the length of the starvation period.

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